PUNCHING TOOL WEAR MODELING USING FINITE ELEMENT METHOD

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurently submitted for award of other degree.

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To my Beloved Family:

JINIKOL BIN LOGIMO
ANSUNGOI BINTI AGALUK

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ABSTRACT

This paper will investigate the factor or parameter that will effect the wear that occur in the punching tool. The punching tool will be redesign by change the shear angle, do the simulation with diferrent force applied to the punching tool by using finite element method and also change the thickness of the punching tool. The purpose of this paper is to investigate the wear that will occur in the punching tool in order to increase the tool life and in the same time will increase the quantity and quality production in the factory. Using finite element method, the parameter of the cause and parameter of the wear in tool will investigate.

ABSTRAK

Kertas projek ini membincangkan atau mengenalpasti factor atau parameter yang akan mempengaruhi kerosakan yang berlaku pada mata pemotong. Mata pemotong akan direka bentuk semula dengan mengubah sudut shear, membuat simulasi dengan mengenakan daya yang berbeza kepada mata pemotong dengan menggunakan cara simulasi dan juga mengubah ketebalan pada mata pemotong. Tujuan kertas projek ini adalah mengenalpasti kerosakan yang akan berlaku pada mata pemotong dengan tujuan meningkatkat kadar hayat pada perkakas dan dalam masa yang sama meningkatkan kuantiti dan kualiti pengeluaran dalam kilang. Dengan menggunakan kaedah simulasi, parameter yang menyebabkan serta parameter kerosakan pada mata pemotong akan dikenalpasti.

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LIST OF SYMBOLS/ABBREVIATIONS

Wad	worn volume per unit sliding distance
V	volume of the material removed by wear from surface
k	wear coefficient
s	sliding distance
H	hardness of the sheet
F_N	normal load applied
β	part of the asperities having the ability to cut
θ	angle of the assumed cone-shaped asperities for the hardest material
γw	wear coefficient depending on sliding contact conditions
V	cutting speed
D	depth of cut
F	feed rate
x, y	determined experimentally
n and C	found by experimentation or published data
Cl	clearance
D and d	die and punch diameter
a_p and b_p	radial and axial wear length of punch

CAD	computer-aided design
IGES	Initial Graphics Exchange Specification

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

In manufacturing industry, tool life was the important factor that controls the quantity of the product. In order to increase the quantity of the product, we need to try maximizing or increase the tool life. There a lot of factor or parameter that will affect the tool life and in the punching tool, wear is the main factor that will decrease the tool life. Tools often show adhesive and abrasive wear in the contact zone.

In this study, we will investigate the parameter that can affect the wear like the shear angle of cutting tool, punching force, and also the type of wear that occur in the punching tool. As a result, we may design the new geometry of the punching tool that less wear occur, mean that it have the higher tool life.

1.2 PROBLEM STATEMENT

Wear are always occur in the machine tool and it will decrease tool life and in some time will affect the production in industry sector. In order to increase the product quantity, the wear that occurs in the tool should be controlled. Using finite element method, we try to investigate the factors or parameter that will lead to this wear that occurs. So, we can try to come up with something new to minimize the wear or increase the tool life. One of the way to increase the tool life is like using the lubricate and we need try to invent the new idea by studying the factors that affect the wear. In this study, we will try to design new geometry of the punching tool by change the shear angle of the punching tool. We do the simulation and find which shear angle that have less stress and strain. It means, the less the stress and strain occur in the punching tool, the wear that occur also less. The stress will affect the wear meanwhile; the strain will affect the edge quality of the punching tool surface.

1.3 OBJECTIVES

The objective of this project is to investigate the wear that occurs in punching tool. The relation between the shear angle, force applied to the punching tool and thickness of the punching tool with the wear that occur in the punching tool will be investigate. Firstly, the geometry of the punching tool will be redesign by change the shear angle. Second, the force that applied to the punching tool also will change and for the third one, the thickness of the punching tool will be change.

1.4 THESIS OUTLINE

This thesis consists of five chapters. Chapter 1 will state the background study, problem statement and objective while chapter 2 consists of literature review. Then followed by chapter 3 regarding experiment setup and design of experiment. Chapter 4 clearly explains the analysis and result obtained during experiment and finally chapter 5 will conclude the whole thesis and some recommended for future planning.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Punching operations are widely used to cut sheet or plates by a shearing process between the punch and the die. Compared with casting, forging, and machining, these processes are usually very easy, fast, and economical to obtain the desired shape, size and finish. In general, the process of shearing and the conditions of the sheared surface are influenced by the punch, the die, the speed of punching, the lubrication, the clearance between the punch and the die, and the properties of the work piece material. The performance characteristics of the punch and the die are determined by the tool geometry and materials, heat treatment, surface treatment, finishing, and the wear of the cutting edge. Singh et al. [1] had studied the design of various types of punches using a finite-element technique. The results of their analysis indicated that the radial deformations of punches with balanced convex and concave shear have a minimum value within the shear-angle range of 17–22°. This suggests that a shear angle of 20° can be proposed safely for practical purposes in order to reduce the stress on the tool or to permit the use of a lower-rated press. Furthermore, eccentricity due to asymmetric load on the press when using a punch with balanced convex shear will be smaller. The effect of high-speed blanking on the sheared edges was studied by Jana and Ong [2]. Their investigations showed that the use of high punch-speeds generally resulted in blanks being produced with an improved surface finish as compared to those obtained at low speed. This improvement is particularly marked for mild-steel blanks. Moreover, at a high punch speed, less distortion was obtained and the width of the strain-hardened region was smaller, but the distortion of the blanks increases with the increase of the radial clearance. Popat et al. [3] had studied the optimum punch–die clearance and punch penetration using a finite-element model. They stated that the optimum punch–die clearance depends on the local fracture strain of the material. The percentage of punch penetration at crack initiation for the optimum punch–die clearance does not depend greatly on parameters such as sheet thickness, work-hardening exponent, ductility, etc. and remains at a value of around 30% of the sheet thickness. Metal cutting tools are subjected to extremely arduous conditions, high surface loads, and high surface temperatures arise because the chip slides at high speed along the tool rake face while exerting very high normal pressures (and friction force) on this face. Cutting tools need strength at elevated temperature, high toughness, high wear resistance and high hardness. A key factor in the wear rate of virtually all tool materials is the temperature reached during operation, unfortunately it is difficult to establish the values of the parameters needed for such calculations, and however experimental measurements have provided the basis for empirical approaches. It is common to assume that all the energy used in cutting is converted to heat (a reasonable assumption) and that 80% of this is carried away in the chip (this will vary and depend upon several factors - particularly the cutting speed). This leaves about 20% of the heat generated going into the cutting tool. Even when cutting mild steel tool temperatures can exceed 550^{o}C, the maximum temperature high speed steel (HSS) can withstand without losing some hardness. There are many type of wear that occur during machining that will affect the product. In industry, the wear in the tool will affect the quality and quantity of the product. If we can control the wear of the tools, we can save a lot of time production and other quality. Some General effects of tool wear include increase cutting forces, increase cutting temperature, poor surface finish and decrease accuracy of finished part. Reduction in tool wear can be accomplished by using lubricants and coolants while machining. These reduce friction and temperature, thus reducing the tool wears.At high temperature zones crater wear occurs. The highest temperature of the tool can exceed 700 °C and occurs at the rake face whereas the lowest temperature can be 500 °C or lower depending on the tool. Energy comes in the form of heat from tool friction. It is a reasonable assumption that 80% of energy from cutting is carried away in the chip. If not for this the work piece and the tool would be much hotter than what is experienced. The tool and the work piece each carry approximately 10% of the energy. The percent of energy carried away in the chip increases as the speed of the cutting operation increases. This somewhat offsets the tool wears from increased cutting speeds. In fact, if not for the energy taken away in the chip increasing as cutting speed is increased; the tool would wear more quickly than is found. The mechanism of wear is very complex and the theoretical treatment without the use of rather sweeping simplifications (as below) is not possible. It should be understood that the real area of contact between two solid surfaces compared with the apparent area of contact is invariably very small, being limited to points of contact between surface asperities. The load applied to the surfaces will be transferred through these points of contact and the localized forces can be very large. The material intrinsic surface properties such as hardness, strength, ductility, work hardening etc. are very important factors for wear resistance, but other factors like surface finish, lubrication, load, speed, corrosion, temperature and properties of the opposing surface etc. are equally important.

2.2 Type of Wear

Type of wear is including the flank wear, crater wear, crater wear and many more. The flank wear is occur in the portion of the tool in contact with the finishing part erodes (relief face) and occur mostly from abrasion of the cutting edge. After an initial wearing in period corresponding to the initial rounding of the cutting edge, flank wear increase slowly at a steady rate until a critical land width is reached after which wear accelerate and become severe. The progress of the flank wear can be monitor in production by examine the tool by tracking the change in size of the tool or machining part. Flank wear can be minimizing by increasing the abrasion and deformation resistance of the tool material and by the use of hard coating on the tools. For the crater wear also known as rake face produce a wear crater on the tool face. Usually, this crater wear does not limit the tool life but will increase the effective the rake angle of the tool and reduce the cutting force. But, for the side effect, excessive crater wear weaken the cutting edge and can lead to the deformation or fracture of the tool. This should be avoiding because, it can shorten the tool life and resharpening the tool more difficult.

2.2.1 Abrasive Wear

Adhesive wear is also known as scoring, gailing, or seizing. It occurs when two solid surfaces slide over one another under pressure. The abrasive wear mechanism is basically the same as machining, grinding, polishing or lapping that we use for shaping materials. Two body abrasive wear occurs when one surface (usually harder than the second) cuts material away from the second, although this mechanism very often changes to three body abrasion as the wear debris then acts as an abrasive between the two surfaces. Abrasives can act as in grinding where the abrasive is fixed relative to one surface or as in lapping where the abrasive tumbles producing a series of indentations as opposed to a scratch. Surface projections, or asperities, are plastically deformed and eventually welded together by the high local pressure. As sliding continues, these bonds are broken, producing cavities on the surface, projections on the second surface, and frequently tiny, abrasive particles, all of which contribute to future wear of surfaces.

2.2.2 Adhesive Wear

Adhesive wear is also known as scoring, galling, or seizing. It occurs when two solid surfaces slide over one another under pressure. Surfaces which are held apart by lubricating films, oxide films etc. reduce the tendency for adhesion to occur. Surface projections, or asperities, are plastically deformed and eventually welded together by the high local pressure. As sliding continues, these bonds are broken, producing cavities on the surface, projections on the second surface, and frequently tiny, abrasive particles, all of which contribute to future wear of surfaces.

The wear resulting from adhesive wear process has been described phenomenological by the Archard equation [6]:

$$W\text{ad} = \frac{V}{s} = \text{K}\frac{F_N}{3H}$$

*W*ad is the worn volume per unit sliding distance; *V* is the volume of the material removed by wear from surface, *k* is a wear coefficient depending on the contacting materials and the sliding contact conditions. *s* is the sliding distance, *H* is the hardness of the sheet and F_N is the normal load applied on the tool. Inspection of Eq. (1) shows that the hardness H is the only material property appearing in the model. Typical values of the wear coefficient k are given in [7,8] for a combination of contacting materials. In the present investigation, the value k was taken in the order of 10E-05. A simplified expression for the volume of abrasive wear can be given by [8]:

$$V=\frac{\beta F N s}{\pi H}\tan(\theta)$$

Where β represents that part of the asperities having the ability to cut and θ the angle of the assumed cone-shaped asperities for the hardest material. If the parameters of the wear models are assumed to be constant through time, the above wear models can be rewritten as:

$$V=\gamma w F \mathrm{N} s$$

where γw denotes a wear coefficient depending on sliding contact conditions [8,9] and varies over the range of 10^{-2}–10^{-7} mm^2/N. In the present paper, γw is taken in the order of 1.3E-04 at the sliding interface of the work piece and the punch. This value corresponds to a hard tool steel.

2.2.3 Erosion

Erosion is caused by a gas or a liquid which may or may not carry entrained solid particles, impinging on a surface. Other explanation: erosion is the wearing away or destruction of metals and other materials by the abrasive action of water, steam or slurries that carry abrasive materials. Pump parts are subject to this type of wear. When the angle of impingement is small, the wear produced is closely analogous to abrasion. When the angle of impingement is normal to the surface, material is displaced by plastic flow or is dislodged by brittle failure.

2.2.4 Fretting wear

Fretting wear is the repeated cyclical rubbing between two surfaces, which is known as fretting, over a period of time which will remove material from one or both surfaces in contact. It occurs typically in bearings, although most bearings have their surfaces hardened to resist the problem. Another problem occurs when cracks in either surface are created, known as fretting fatigue. It is the more serious of the two phenomena because it can lead to catastrophic failure of the bearing. An associated problem occurs when the small particles removed by wear are oxidised in air. The oxides are usually harder than the underlying metal, so wear accelerates as the harder particles abrade the metal surfaces further. Fretting corrosion acts in the same way, especially when water is present. Unprotected bearings on large structures like bridges can suffer serious degradation in behavior, especially when salt is used during winter to deice the highways carried by the bridges.

2.3 Wear resistance

Surface hardness is often regarded as the basis for good wear resistance. The wear resistance improvement of the nanostructured coatings obtained from nanostructured powder could be ascribed to both the decrease of the defects size and the grains size. Furthermore, the higher fracture resistance of nanostructured coatings is due to a unique microstructure generated under appropriate plasma spray conditions and composed of a mixture of fully melted splats and partially melted particles. The partially melted regions can provide a variety of cracks arrest and deflection mechanisms, thereby increasing the crack growth resistance of the coating[4].

2.4 Tool life

Tool life is the most important practical consideration during selecting the cutting tools and cutting condition. Tool which wear slowly have a low per part cost and produce predicable tolerances and surface finishes. An understanding of tool life required an understanding of the ways in which tool fail. Tool failure may result from wear, plastic deformation or failure. Tools deform plastically or fracture when they are unable to support the load generated during chip formation. Research had been doing to develop method of predicting tool life from a consideration of tool failure mechanisms. Unfortunately, accurately predicting tool life in any general sense is very difficult because tool life depends strongly on part requirements. In practice, tools are removed from service when they no longer produce an acceptable part. This may occur when the parts dimensional accuracy, form accuracy, or surface finish are out of tolerance, when an unacceptable burr or other edge condition is produced or when there is an unacceptable probability of gross failure due to an increase in cutting forces or power. Tools used under the same conditions in different operations may have quite different usable lives depending on critical tolerances or requirement. Because of this fact, methods of predicting tool life are useful primarily for comparative purpose, for example in ranking expected levels of tool life for different work materials, tool materials or cutting condition [5].

2.4.1 Taylor Equation for Tool Life Expectancy

The Taylor Equation for Tool Life Expectancy provides a good approximation.

$$V_c T^n = C$$

A more general form of the equation is

$$V_c T^n \times D^x f^y = C$$

Where V_c is cutting speed, T is tool life, D is depth of cut, F is feed rate, x and y are determined experimentally, and n and C are constants found by experimentation or published data; they are properties of tool material, work piece and feed rate.

In punching processes, clearance can be expressed as a percentage of the sheet-metal thickness:

$$\text{Cl } (\%) = \frac{D-d}{2t} \times 100$$

Where *D* and *d* are the die and punch diameter, and *t* is sheet-metal thickness, as can be seen in Figure below.

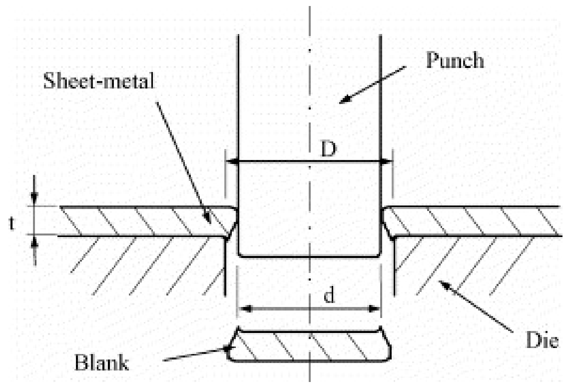

Figure 2.1: Geometrical parameters of the punching experiments.

Source: After J.J. Hern´andez, P. Franco, M. Estrems, F. Faura (2006)

2.5 Tool wear

In punching processes, the cutting tool edge is exposed to strong tribological efforts because of the high normal contact pressure and sliding distance. Cutting tools often show adhesive and abrasive wear in the contact zone.[14] Generally, the total worn area can be expressed as the addition of three terms: flank wear, face wear and tip wear (Fig.2a). . As can be seen in (Fig.2b), the worn surface of the tool presents a triangular shape [10] and the expression of the worn area is

$$S_p = \frac{a_p \, x \, b_p}{2}$$

where a_p and b_p are the radial and axial wear length of punch, respectively. The loss of cutting tool material is not uniform but strongly irregular along the cutting edge [11].